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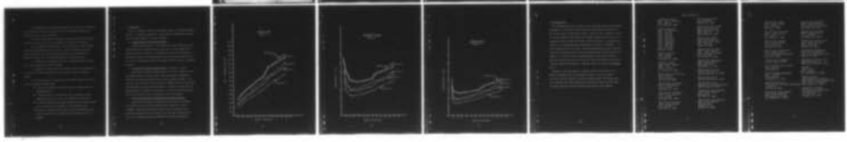

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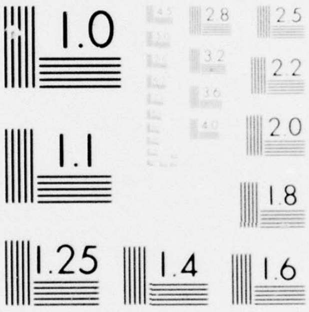

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ENERGY CONTROL SYSTEM STUDY
FOR
FORT BELVOIR, VIRGINIA

NMD and ASSOCIATES
Alexandria, Virginia

25 July 1977

FINAL REPORT

APPROVED FOR PUBLIC RELEASE
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[illegible] SUPPORT AGENCY
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Prepared for

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Research and Technology Division
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

A computerized analysis of the feasibility and cost of providing a central energy control system at Ft. Belvoir, Virginia. Results include listing of buildings, initial installation costs, payback determinations, energy savings, dollar savings and maintenance and operating cost estimates. The methods and logic of the study may serve as a guide for similar analysis for other military facilities.

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ENERGY CONTROL SYSTEM STUDY

FOR FT. BELVOIR, VIRGINIA

A. SUMMARY

The following is a summary of recommendations resulting from a feasibility and economic analysis for supplying an automated energy control system for Ft. Belvoir, Virginia. Details are contained in the body of this report.

1. Number and types of buildings:

The automated control system should extend to 128 buildings. The computer printout shows only 120 buildings because, in some cases, buildings were combined for easy analysis. Buildings selected range in size from 3600 sq. ft. to 174,000 sq. ft. with an average of approximately 30,000 sq. ft. The great majority of the buildings are both heated and air conditioned. These structures consume about 32 percent of the total post energy requirements.

2. Estimated costs:

The following costs and payback estimates (average of five companies) do not include possible necessary changes to heating and air conditioning equipment or new equipment to accomodate the control schemes.

a. Initial overall project cost (b plus c below and escalated to program year)	$ 1197312
b. Initial local wiring, remote point and telephone line equipment costs	$ 814577
c. Initial central console cost (including software)	$ 151390
d. Maintenance and operation (annual cost)	$ 109848

3. Payback estimates (average of 5 companies):

   a. Discounted payback ------------------------------- 4.99 years

   b. Simple payback ------------------------------------ 3.57 years

4. Calculated annual energy consumption of 128 buildings:

   a. Baseline cooling consumption -------------------- 113.7×10^9 BTU

   b. Baseline heating consumption -------------------- 222.3×10^9 BTU

   c. Percentage of base total heating usage ----------- 29 %

   d. Percentage of base total electrical usage -------- 37 %

5. Calculated energy savings (BTU's and dollars -- dollars escalated to program year):

   a. Annual dollar savings of 128 buildings ----------- $ 335085

   b. Annual BTU savings of 128 buildings -------------- 57.8×10^9 BTU

      1. Heating savings ------------------------------ 42.9×10^9 BTU

      2. Cooling savings ------------------------------ 14.9×10^9 BTU

   c. BTU saved per dollar invested (annual) (average of 5 companies) ---------------------------------- 49138 BTU

   d. Percent dollar savings of total current base usage- 5.13 %

   e. Percent energy savings of total current base usage- 5.44 %

   f. Percent energy savings of 128 building usage ------ 17.2 %

      1. Percent heating savings ---------------------- 19.0 %

      2. Percent cooling savings ---------------------- 13.0 %

6. System capability:

The system will be a computerized, on-line, real-time, self-contained multi-tasking, multi-strategy, optimizing, solid-state electronic control and monitoring system. The system is intended to provide full interactive and strategic surveillance and control of the building

heating, ventilating and air conditioning systems. The system will provide for modular, non-proprietary expansibility to facilitate the connection of additional points, functions, software programs, peripheral equipment and utility systems.

7. System limitations:

The initial system will not include non-energy related features such as fire alarms, intrusion alarms and maintenance scheduling although these may be added later if desired.

8. Special capability:

The system can provide central control for peak shaving and for priority and selective equipment operation in the event of a power shortage.

9. Special recommendations:

a. If it is determined to proceed with the project, a detailed inspection should be made to establish the extent and costs of necessary changes to building heating and air conditioning equipment. Re-analysis should then be accomplished by computer to see if additional buildings might be added while still remaining within payback period requirements.

b. As part of the overall project, a study should be made concerning the value of using local timing devices or mini-processors on the smaller buildings on the base. Guidance for making such an evaluation will be available soon from the Facilities Engineering Support Agency.

B. PREFACE

The installation of automated, computerized control systems is being considered by many military facilities as one means of reducing energy consumption and energy related costs. The purpose of this study is to examine the feasibility of such a system for Ft. Belvoir and to determine the scope, costs and potential savings in sufficient detail to provide justification for a viable construction project.

Fort Belvoir is an Army post located in northern Virginia containing a typical variety of structures common to most military installations such as; barracks complexes, administration buildings, family housing, industrial buildings, training facilities, storage structures, etc. The post is comprised of 204 acres (8.891×10^6 sq. ft.) with an approximate military and civilian population of 17,540. Design conditions are 11°DB for heating and 90°DB and 76°WB for cooling, indicating that considerable energy expenditures are required for both summer and winter seasons.

Although a few small central heating and cooling plants have beein installed, the preponderance of the buildings contain their own individual boilers and air conditioning units. The prime sources of energy for heating and air conditioning are No. 2 fuel oil and electricity, respectively. Current fuel costs are 40 cents per gallon for No. 2 fuel oil and 3 cents per KWH for electricity.

The concept of central control and operation is not intended to be used in lieu of other obvious cost effective practices such as caulking, insulating and thermopane installation, but rather in conjunction with them.

C. BODY OF REPORT

1. Introduction

Past experience has shown that energy savings can be achieved through positive regulation of existing heating and air conditioning systems. In looking at a large post such as Fort Belvoir, the basic assumption was that a central computerized control system would be most desirable to serve the larger energy intensive buildings and would provide maximum flexibility and capability for expansion and addition of other functions. Smaller buildings would most likely be economically controlled by use of individual mini-processors or time clock devices.

This analysis involves the determination of the cost effectiveness of a range of buildings which could be centrally controlled to effect energy savings. The data presented will permit an informed evaluation for decision making purposes regarding the size, scope, cost and benefits of a computerized control system for the post. The analysis is restricted only to energy related evaluations and does not include other features which may be added at a later date to the computerized system such as; fire safety, intrusion alarms and maintenance functions. It is extremely difficult to assign acceptable and verifiable cost benefit values to such functions, and thus they are subject to further examination.

Some of the values and factors used in the analysis were averages rather than specific verified quantities. However, it is our judgement that final figures are accurate to within a range of plus or minus 5 percent.

2, Investigation

a. Desired data: Initially it was necessary to establish specifically what final data would be required to determine the scope of a feasible automated control system for Fort Belvoir. Essentially these are as follows:

(1) Identification of number and types of buildings to be controlled.

(2) Types of control systems for each building.

(3) Determination of base line energy usage.

(4) Estimate of potential energy savings.

(5) Estimate of initial and maintenance and operating costs.

(6) Simple and discounted payback periods.

b. Development of computer program: Because of the large number of computations involved, it was determined that the best procedure would be to develop a computer program utilizing guidance contained in the following publications:

(1) "Automation and Centralization of Facilities Monitoring and Control Systems:, Report No. ED 76-1, Reynolds, Smith and Hills.

(2) AR No. 11-28 "Economic Analysis and Program Evaluation for Resource Management", Jan., 1976.

Computer program detail and a guide to program usage are contained in the following publications:

(1) "Installation Energy Control System Analysis Calculation Program" June, 1977 (Attached as Appendix I).

(2) "Guidance for Energy Control System Analysis", FESA-RT 2023, March 1977 (Attached as Appendix II).

The first step in computer program development was to catagorize the buildings by functional types as listed below. This breakdown was used to correspond to the energy usage data gathered, known and calculated.

TABLE I

BUILDING CATAGORIES

BUILDING TYPE NO.	BUILDING TYPE	BUILDING TYPE NO.	BUILDING TYPE
001	E. M. Recreational Center	010	Chapel
002	Theater	011	Library
003	Bowling Alley	012	Office Building
004	N.C.O. Club	013	Laboratory (oil)
005	Post Exchange	014	Laboratory (gas)
006	Commissary	015	Barracks
007	E.M. Mess	016	B.O.Q.
008	Laundry	017	Machine Shop
009	Field House	018	Warehouse
		019	Dental Clinic

The second step in computer program development was to determine the various types of typical energy savings control schemes which could be used in conjunction with the heating and air conditioning systems usually found in the buildings listed in Table I. These schemes are as follows:

(1) Scheme 1. Equipment Shutdown. Programmed shutdown of building heating and cooling equipment during unoccupied periods. The magnitude of savings depends on the heat transfer characteristics of the building, equipment capacity, type and operating efficiency, and outside temperature and humidity conditions.

(2) Scheme 2. Outside Air Shutoff. Consists of closing outside air intakes and shutdown of exhaust fans when the building is unoccupied. Scheme 2 is normally used in conjunction with Scheme 1.

(3) Scheme 3. Outside Air Reduction. May be a one time adjustment of the outside air damper or may be a variable setting control.

(4) Scheme 4. Enthalpy Control or Enthalpy Optimization. A popular energy conserving scheme is enthalpy control. By measuring the temperature and the relative humidity, an estimate of the total heat content (sensible and latent) of both return and outside air streams can be made. Then the air stream requiring the least amount of energy to maintain the proper comfort level is used for the supply air. An extension of the concepts described in enthalpy control is that of enthalpy optimization. This control scheme mixes the air streams (outside or return air) which will impose the lowest cooling load on the mechanical equipment.

(5) Scheme 5. Temperature Reset. Reset or adjustment of air temperature in mixed air systems like double duct or multizone. The basic concept is to decrease the amount of mixing by reducing the temperature difference between the hot and cold streams.

(6) Scheme 6. Peak Reduction. Shutting down selected equipment (shedding) when desirable to reduce a peak during any demand interval.

The next step was to develop the base load characteristics of each of the types of buildings and further to estimate the percentage of savings which would be achieved by use of the above listed schemes. Base loads were developed by use of computer programs such as E-Cube and examination of other data such as oil deliveries, electrical charges and other energy billings. Weighted judgements were made to arrive at average factors. Energy savings factors for each scheme were taken from a recently prepared FESA design manual.

Folowing load and load saving factor determinations, costs were estimated for local wiring, remote points, telephone line equipment and computer hardware.

These estimates were furnished by five suppliers representative of the industry.

Finally, necessary computations and formulas were derived to provide the desired computer output. In addition to the output previously described, the data includes cumulative Btu's saved per dollar invested as well as the cumulative total energy savings per year in dollars. These final figures are presented for each of the five representative suppliers.

3. Procedure

a. A copy of the building information schedule for Ft. Belvoir was obtained from the post facilities engineer. This schedule is a compilation of various parameters for each building on the post. The parameters include total square footage, HVAC system types, building use and utility service to the building.

b. A tentative list of candidate buildings was selected from information contained in the building information schedule. Selection was made primarily on the basis of building size, usage, and type of heating and cooling system.

c. All available electric and oil bills for the buildings selected were collected and analyzed together with other load information. Average loads on a square foot basis were generated for each of the nineteen types of buildings.

d. Information was obtained on the HVAC systems in each of the candidate buildings and applicable savings schemes were assigned for each structure.

e. Using heating and cooling savings factors, total heating and cooling savings per year per building were determined by computer for each of the schemes proposed. Savings are stated in GBTU/year ($G = 1 \times 10^9$). Only the first four schemes of the six previously described were used in the Fort Belvoir study since insufficient data (such as building ventilation capacities and electrical loads) was available to input schemes 5 and 6.

f. The building control point tabulation was input into the computer. This listed the control points required for each building and scheme as; start-stop, reset, analog and binary.

g. Based on the number of points and their location in the building, total local wiring costs for each building were generated by computer.

h. The computer compiled remote point cost totals for each building by combining individual start-stop, reset, analog and binary point costs. Since these costs vary with individual suppliers, this information was computed for each of the five manufacturers who provided cost data.

i. Telephone line equipment costs were established (again for each of the five suppliers) for each building.

j. Equipment and wiring costs were added to provide individual building total costs and overall project cost for each of the five supplier's systems.

k. The final computer operation was an economic analysis for each of the five supplier's systems which:

(1) Listed the buildings by relative merit of savings minus cost of implementation.

(2) Listed operating and maintenance costs and control system implementation costs as well as the cumulative total costs.

(3) Indicated discounted and simple payback periods. Simple payback costs and savings were escalated to the programmed year.

(4) Listed the cumulative Btu's saved per dollar invested as well as the cumulative total escalated energy savings per year in dollars.

4. Conclusions

Below is a summary, together with graphic figures of the final computer analysis. A complete computer run is available for inspection and review from Dr. Hollis, FESA, Ft. Belvoir, Virginia.

a. Total ECS System Cost (128 buildings).

As indicated in figure 1., ECS system total costs ranged from about $.94 million to $1.4 million with the average of the five suppliers at slightly under $1.2 million. The slopes of the curves of the number of buildings vs dollar costs approximate straight lines which indicates that the cost for incremental addition of buildings to the system is relatively constant.

b. Discounted and Simple Payback Periods. (figures 2. and 3.)

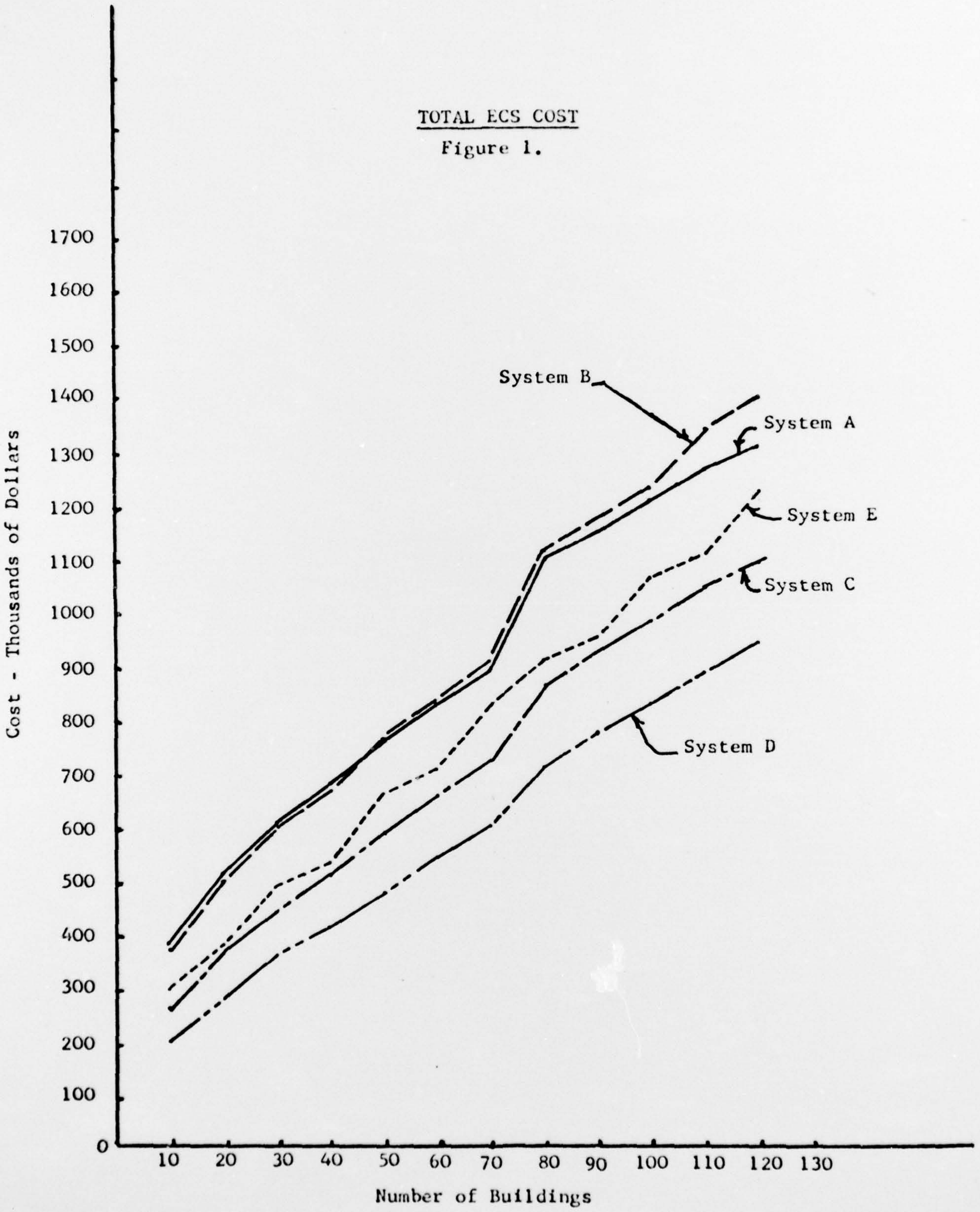
Discounted and simple payback periods for all five suppliers at the 120 building mark fall within higher level justification requirements (10 years for discounted payback and 6 years for simple payback). It is apparent that the shapes of these curves are similar and vary in amplitude in proportion to the total ECS system cost. It should be noted that the optimum number of buildings in all cases, so far as the shortest payback periods are concerned, are in the range of 20 to 40 buildings.

c. Total Energy Savings and BTU's Saved per Dollar Invested.

Since all five systems are identical in their control sequences, total annual energy savings in dollars will be identical at about $ 335085. BTU's saved per dollar invested vary in accordance with previously determined total investment costs and range from 41134 BTU for the most expensive system to 61288 BTU for the least expensive.

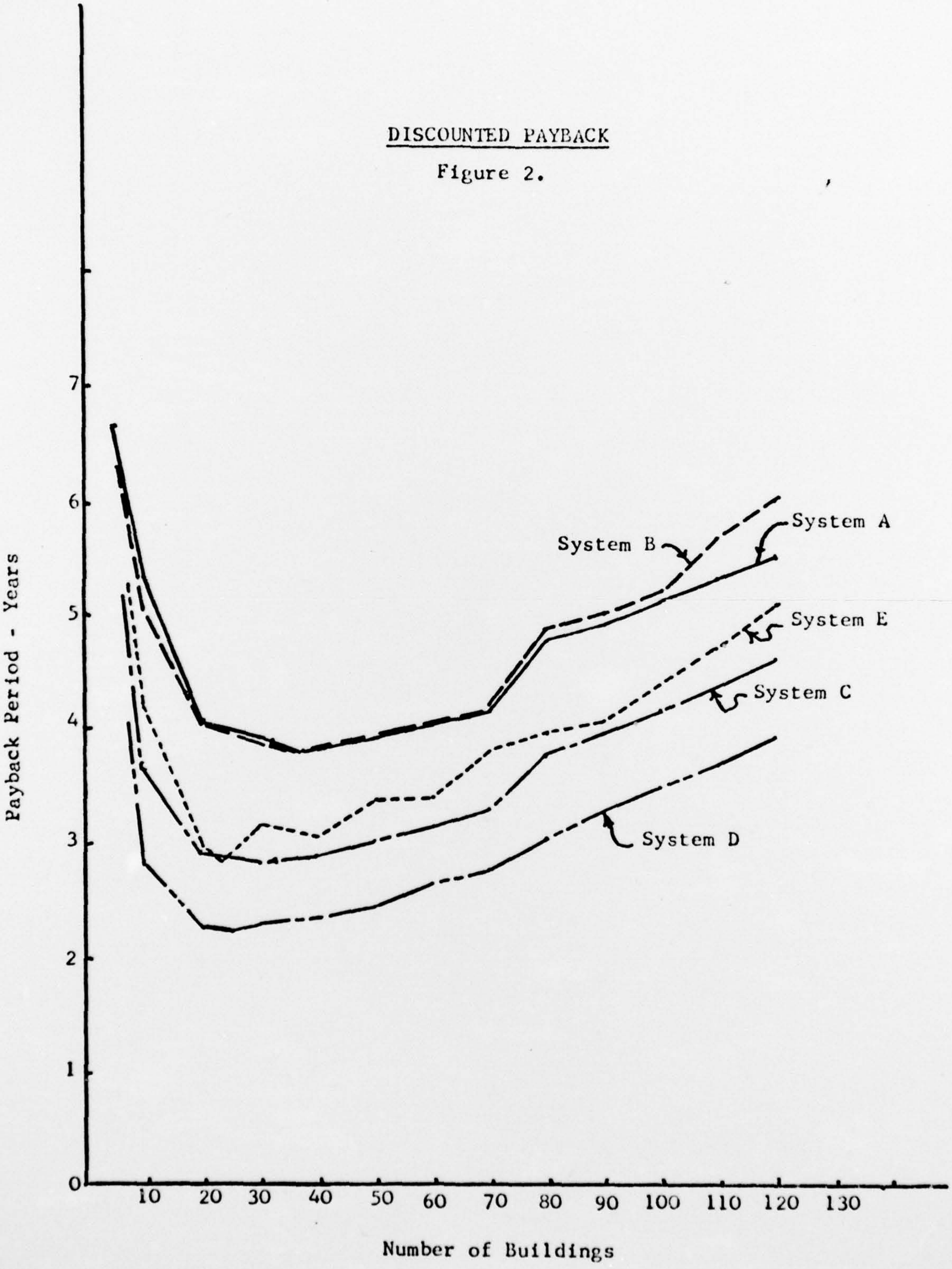
TOTAL ECS COST

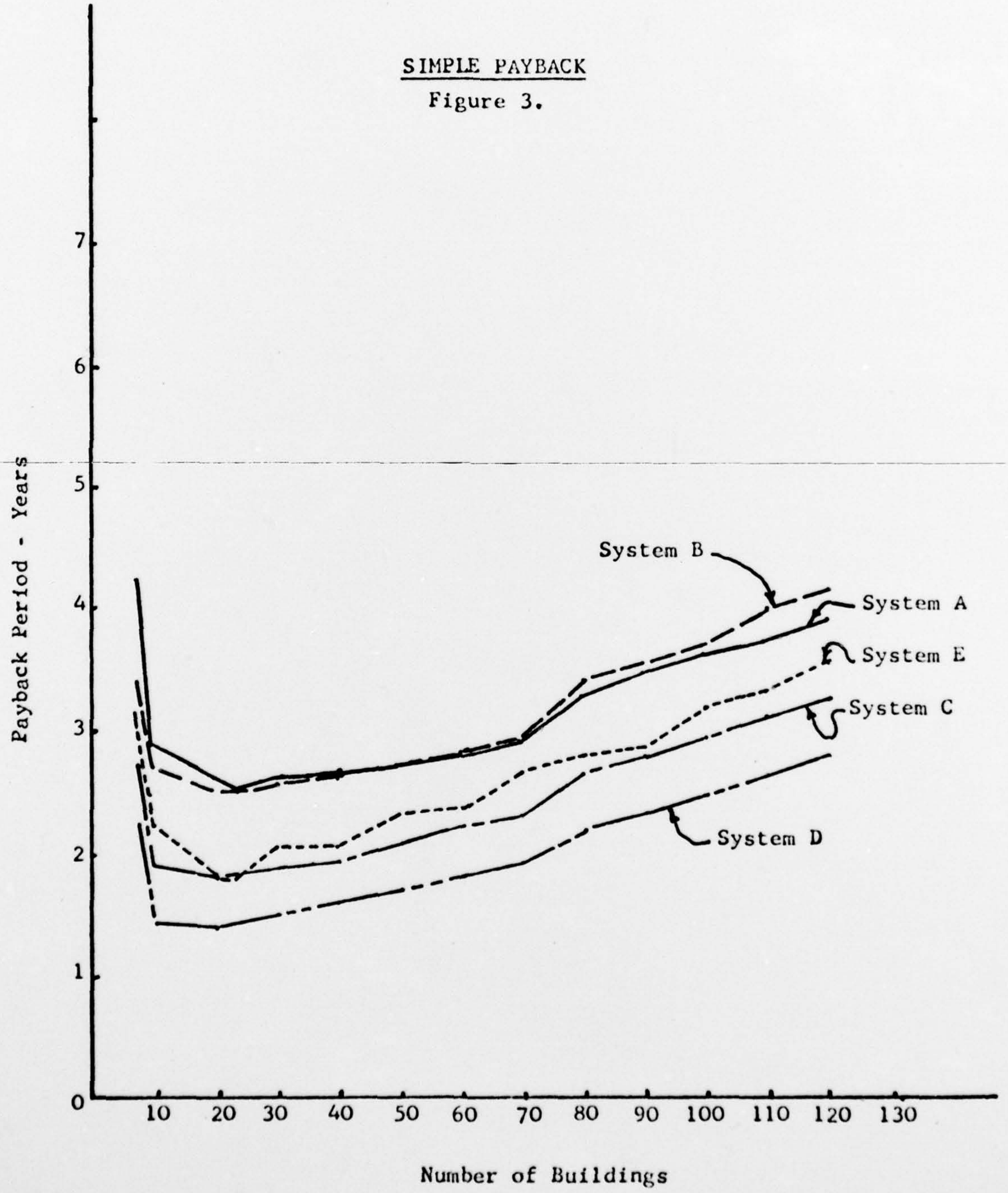
Figure 1.



DISCOUNTED PAYBACK

Figure 2.





SIMPLE PAYBACK

Figure 3.

5. Recommendations

The buildings selected for study were the large high energy users and thus susceptable to significant energy savings through controlled operation of the heating and air conditioning systems. Since the costs analyzed for each of the five suppliers fell within the economic justification criteria, it is recommended that the full 128 building system be approved. For purposes of funding, it is recommended that initial costs of system B ($ 1404071) be used in preparation of form 1391. The associated payback periods, Btu saved per dollar invested and other related data should also be those computed for supplier B. The use of these more conservative figures should provide a monetary safety factor since there has been little experience to verify cost estimates furnished by suppliers. Specific figures are shown under SUMMARY page 1.

Although no detailed analysis was made as part of this study, it is further recommended that consideration be given to the use of microprocessors and time clocks for smaller buildings (under 7500 square feet). It is expected that short payback periods for these control systems could be effected because of the low initial installation costs involved.

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